On the Morphology of the Pedipalpi.

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(Plates III.–V.)

I. Anatomy of *Thelyphonus*.

The internal anatomy of the *Pedipalpi* has, so far as my knowledge of the literature goes, never been described in any great detail *; and though the following notes do not pretend to touch on more than a few points, it seemed worth while to record them, if only by way of calling attention to the need for further investigation. That my material was limited in quantity and badly preserved, is the only excuse I can offer for the incompleteness of my observations, any attempts to trace the distribution of the nerves or the details of the reproductive system having been in vain. Sections through the whole animal were tried with some small specimens; but, apart from the difficulty of cutting an animal so abundantly provided with chitin, the inside was found to have lost all minute structure, and it was almost impossible to discriminate between the various organs.

Before entering on the subject of this paper, I wish to make a protest against the indiscriminate way in which Arthropod appendages are named. To take an example: an appendage is spoken of as "the third leg." Now this may mean (1) the third appendage; (2) the third postoral limb, *i. e.* appendage iv.; (3) the third walking-leg, which is in Scorpions appendage v., and in forms like *Phrynus*, in which appendage iii. is modified for tactile purposes, it may be either appendage v. or appendage vi. If one follows the same name through the Crustacea, the result is even more bewildering. The use also of terms such as antennæ, mandibles, &c. is objectionable, as implying homologies with other groups which are by no means certain; and it would be a great gain if writers would simply talk of the appendages by their number.

The hard parts of *Thelyphonus* are pretty well known, thanks to the works of systematic zoologists; but it will perhaps not be out of place to give a brief description of the chief points, especially as there are one or two new details to be noted. The sclerites of the dorsal surface may be dismissed in a few words as consisting

* The only figures with which I am acquainted are those of Blanchard in 'L'Organisation du Règne animal.'

of the carapace, behind which come nine band-like sclerites, the body ending in the three narrow, cylindrical sclerites of the tail. The second to eighth sclerites show depressions which indicate the points of attachment of the dorso-ventral muscles. On the ventral surface the carapace is bent over in front for a short distance. This infolded part is marked by a strong median longitudinal ridge which helps to separate the bases of the cheliceræ.

The *cheliceræ* (Pl. IV. fig. 13) are two-jointed, the distal joint being claw-shaped; it is strongly articulated to the first joint at the upper edge and folds down across its end, the point reaching to the lower edge. The proximal joint is roughly rectangular, as seen from the side, the length being about twice the breadth. In section the shape is an elongated oval, the long axis being dorso-ventral in direction. The surface of this joint is smooth except toward the distal end, where it is furnished, on the inner side, with a thick crop of hairs. The cheliceræ are not articulated to the rest of the skeleton, but attached by thin membrane to the thick membrane which forms the front of the cephalothorax in such a way as to be capable of being retracted for more than half their length (Pl. III. fig. 1).

The *second* pair of appendages are very powerful, and consist of six joints. In the middle line the first joints are fused together for about two thirds of their length, thus completely shutting in the mouth behind. Being thus fused, the first joint can no longer function as a jaw, as it does in the Scorpions, and the biting-function is consequently taken on by the second joint. Anterior to the point where the fusion ceases, the inner surface of the first joint has an organ corresponding to what has been termed the pseudotrachæa in Scorpions and *Phalangidæ**, and which Gaubert† has shown to exist in *Phrynus*. This organ consists in *Thelyphonus* (Pl. IV. fig. 13, *p.s.t.*) of a trapezoidal area of thin skin closely covered with hairs. Except along the ventral margin the hairs are stout, with a well-marked central cavity, and covered with minute secondary hairs which give them a feathery appearance. Along the ventral margin is a ridge bearing stronger hairs, which, however, have not the feathery structure. At the anterior end is a small chitinous plate covered with short spines and bearing one or two long bristles which are

* Macleod, Bull. de l'Acad. Belg. vol. viii.

† Gaubert, Ann. Sci. Nat. sér. 7, vol. xiii. p. 140.

attached in the middle of circular thin areas, while just in front of this plate is a large bunch of simple bristles.

In the membranous area, bounded below and at the sides by the basal joints of the second pair of appendages, and at the top by the carapace, lies the opening of the *mouth* (fig. 13, *m.*). This is at the end of a short cylindrical tube, and is set round with hairs. The tube is strengthened below by a small chitinous plate with serrate anterior margin (fig. 13, *m.t.s.*), and above by the stronger and more important epistoma or camerostome. This epistome passes back through the membranous body-wall and projects into the interior of the thorax as three spines which reach as far back as the brain. These spines serve for the attachment of muscles connected with the stomodæum.

The rest of the ventral surface of the thorax is covered by two sternal pieces and the basal joints of the three walking-legs, which are fused to the body. The third appendage, which is long and slender and tactile in function, is attached close under the carapace to a membranous area lying between the second and fourth appendages. The posterior sternal piece is a truncated triangle in form, the posterior margin being bent up dorsally. Just beyond the end of this bent-up portion is a separate transverse piece of chitin, to which the dorso-ventral muscle from the second dorsal sclerite is attached.

The majority of the ventral *abdominal sclerites* want no special description, being almost precisely similar to the dorsal ones. This, however, is not the case with the first and second. The first sclerite, which we may term the *genital plate*, covers the ventral surface of the first two segments. The genital duct opens behind it, and under it at each side lies the first pair of lung-books. Round the posterior margin the chitin is bent in for a short distance in the middle line, but considerably more towards the sides. There are no dorso-ventral muscles inserted in this plate, those of the second tergite being, as mentioned above, inserted in front of it.

The second ventral sclerite (Pl. IV. fig. 14) corresponds to the third tergite; but owing to the great development of the genital plate it lies somewhat behind its proper position. The third ventral sclerite is narrower than the rest, for the same reason. The second sclerite resembles the first in covering a pair of lung-books which are situated at the sides, as well as in having the posterior margin bent in. This bent-in portion is very narrow

except at two points, one on each side of the middle line, where it runs forward into triangular processes. To the middle of the front edge of this sclerite is attached a chitinous plate, which runs forward forming the dorsal wall of the genital vestibule. The dorso-ventral muscles from the third tergite are attached on each side of this process.

There is little doubt that the genital plate corresponds to the genital plate of the Scorpion, and is an appendage; and I am inclined to consider the second sclerite as also an appendage. If, as I have tried to show in the Scorpion * and as Macleod † maintains in Spiders, the lung-books are derived from the adhesion of abdominal appendages to the ventral surface, there must have been an appendage here in the course of development, and at a comparatively late stage in the development of *Phrynus* ‡ this plate has quite a different appearance from the succeeding segments. The inturned posterior margin also and the absence of a dorso-ventral muscle inserted in the plate itself are suggestive, though I would not attach too much weight to the muscle as the points of insertion of such structures readily change. If this plate is to be regarded as an appendage, the anterior chitinous process to which the dorso-ventral muscle is attached naturally suggests itself as the corresponding sternite. This point also I would not lay much stress on until the development of this region is better known.

Internal Anatomy.

The greater part of the cavity of the abdomen is occupied by the enormous digestive gland—the so-called liver—which forms a solid mass concealing at first sight everything except the heart and a few muscles.

The *heart* (Pl. III. fig. 1) is about the same size from end to end of the abdomen, disappearing at the posterior end beneath a conical mass of muscle connected with the three caudal segments, and anteriorly passing into the thorax, about halfway up which it passes in among the folds of the stomach. Injection being impossible, no attempt was made to trace the further course of either end of the heart. A meshwork of small vessels, consisting of a pair of longitudinal vessels at each side with a transverse vessel in each somite, lies on the surface of the digestive gland, and is probably part of the blood-system.

* Zool. Anz. 1892. † Arch. Biol. vol. v. ‡ *Vide infra*, p. 34.

Underneath the heart lies the *gut*, which merits a somewhat full description. It commences at the mouth with a long stomodæum, which is lined by a thin chitinous cuticle. The anterior part of this stomodæum has muscles passing dorsally and laterally from it to be attached to three chitinous processes, which run back from the epistoma (camerostome) nearly as far as the brain. There is no appearance of a dilatation into a sucking-stomach such as is found in the Scorpion. A transverse section of the stomodæum (Pl. III. fig. 2 *a*) shows a folding-down of the dorsal side like the typhlosole of a worm. The sides of this down-folding are straight and covered with cuticle of the same thickness as that lining the walls of the stomodæum, while the free ventral edge of the fold is irregular in form and covered by much thinner cuticle. The only function I can suggest for this fold is that it acts in some way as a valve to assist in sucking.

Just behind the brain the stomodæum opens into the mesenteron (figs. 1 and 2). The first (thoracic) portion of this is expanded into wide lateral diverticula, which extend over the brain in front and the coxal gland at the sides. Each diverticulum is divided into five lobes, the cavity of most of which seems to be a simple space. The front diverticulum, however, and perhaps portions of the others, is cut up by a meshwork of tissue (fig. 1 *a*), the object of which is, I imagine, to afford a greater surface. The histology of this region I have not been able to study in any great detail; but it is evident that the thoracic diverticula are very different in structure from the abdominal diverticula or "liver." In addition to these lateral diverticula, there are two median ones from the ventral surface (fig. 2, *m.d.g.*). These pass through the entosternite, one going through the large oval anterior aperture in it and the other through the smaller posterior aperture (fig. 4). Ventral to the entosternite, these diverticula run forwards between it and the thoracic ganglion as simple tubes.

The middle portion of the mesenteron opens into the large diverticula of the digestive gland or "liver." There appear to be four pairs of these diverticula, the last one being very much the largest and opening from the gut about the fourth free segment. Behind the fourth segment the gut runs as a narrow tube as far as the seventh segment, and then expands into the large hourglass-shaped stercoral pocket (fig. 3). The peculiar shape of this stercoral pocket is due to its being compressed by the dorso-ventral muscles of the eighth free segment. The

posterior part is a great deal larger than the anterior, and fills the greater part of the ninth free segment. The epithelium lining the stercoral pocket (Pl. IV. fig. 15) consists of flat cells containing numerous granules, which stain darkly with hæmatoxylin along the outer edge. They are very similar to the cells lining the rest of the intestine. The *Malpighian tubes* arise near the posterior end of the stercoral pocket and run forward along the sides of its ventral surface. They are somewhat coiled and closely attached to the pocket by connective tissue. In section they are found to possess an indistinct lumen surrounded by large cells with distinct oval granular nuclei. Occasionally darkly staining granules appear in the protoplasm, but for the most part it is apparently structureless (Pl. IV. fig. 16). The coils of the Malpighian tubes are surrounded and held together by fibrous-looking connective tissue.

The *proctodæum* is a short straight tube running back through segments 10–12 to open below the telson. A slight thickening marks its junction with the mesenteron close behind the stercoral pocket. The epithelium lining it is thrown into folds, and consists of long cells with apparently a cuticle over their outer surface (Pl. IV. fig. 17). The distinction between these cells and those lining the stercoral pocket is quite evident, and the transition from one form to the other somewhat abrupt.

In describing the stercoral pocket as part of the mesenteron, I have been influenced by the character of the epithelium lining it and passing forward into the intestine without any break, while differing so markedly from that lining the proctodæum, and also by the point of origin of the Malpighian tubes. The condition of things in the embryos of *Phrynus*, which are described below, admits of little doubt as to the origin of the stercoral pocket from the mesenteron.

The *entosternite*, which is so characteristic of Arachnids, deserves a few words of description in this form (Pl. III. fig. 4). It lies between the gut and the thoracic ganglion, and is best described as an elongated plate drawn out into a number of processes. The front margin of it lies immediately behind the cerebral ganglion, and a pair of processes run forward one on each side. A large oval foramen perforates the plate near its front end, through which the anterior median diverticulum of the gut passes. Near the level of the posterior end of this foramen a second pair of processes passes onward and dorsalward. A little

behind the large oval foramen lies a small subcircular one, through which the posterior median diverticulum of the gut passes, and a third pair of processes is given off at about the level of the front of this circular foramen. Behind this second foramen the entosternite is a solid plate. At first it narrows somewhat, but soon expands again and runs out into the fourth and last pair of processes. This entosternite is more complicated than is usual in Arachnids, and this is probably to be correlated with the greater development of the thorax and its appendages. The processes into which it is drawn out serve for the attachment of muscles. The first pair of processes has muscles from it to the large second pair of appendages, while the other three serve for the muscles of the three walking-legs, the thin third pair of appendages being without any special process.

The *nervous system* is almost entirely concentrated in the thorax. The cerebral ganglia are small oval structures placed far back in the thorax (Pl. III. fig. 4) and giving rise to two pairs of optic nerves. The far back position of these structures is due to the large cheliceræ which, when drawn in, occupy almost the whole of the region in front of the brain. The three processes from the epistoma, of which mention has been made, also reach as far as the brain. The thoracic ganglion (fig. 5) is subtriangular in form, and gives rise to the nerves for the greater part of the body. The origin of the nerves to the first two appendages could not be clearly made out, as the front part of the ganglion is somewhat entangled in chitinous processes which come in from the floor of the thorax. The nerves to appendages iii. to vi., however, are quite distinct, and the posterior end of the ganglion finally gives off a paired nerve-cord, alongside of which run a number of fine nerves, the course and distribution of which I failed to trace. The nerve-cord runs straight back without any ganglia till it reaches the ninth free segment, in which there is a small oval ganglion lying on the top of the right stink-sac (fig. 6). A nerve passes out laterally from each side of this ganglion, and a pair pass also posteriorly into the tail.

The *reproductive organs* have been recently described *, but as the paper only gives two schematic figures it is not of much assistance in dissecting out these parts. Both the specimens which I dissected were males, and their reproductive organs were disposed as follows:—The testes are a pair of straight

* Biol. Centralbl. ix.

tubes which lie side by side near the middle line, reaching as far back as the eighth free segment. In the third and fourth free segments they become narrowed into short vasa deferentia, which open into the enormous seminal vesicles situated one on each side of the first segment (fig. 8). These seminal vesicles open in the middle into what may be termed the genital vestibule, which runs straight back to open to the exterior at the posterior edge of the genital plate. The dorsal wall of the posterior part of this genital vestibule is formed by the median anterior process of the third segment. Each of the seminal vesicles contains two hard brown structures in the form of curved grooved rods. One pair of these rods is united in a plate-like expansion in the middle line. The other pair seem to be independent of each other. No muscles could be found in connection with these structures, and their function—except in so far as they serve to keep the seminal vesicles dilated—is not evident. The walls of the genital vestibule are strengthened by two curved chitinous bars (fig. 8, *cl*), which seem independent of the genital plate, though coming into close contact with its inturned margin at their posterior ends. A small ring of chitin (Pl. III. fig. 8, c^2) also lies in the dorsal wall of the vestibule in front of the median anterior process of the third segment.

Underneath the testes, underneath even the nerve-cord, lies, in the middle line, the right sac of the *stink-gland* (fig. 6). It is in contact on the ventral side with the body-wall and reaches forward as far as the fourth segment, and the width is about half that of the space between the dorso-ventral muscles. Traced backwards, it narrows considerably in the tail-segments, and passing to the right of the rectum opens close to the middle line between the anus and the base of the telson. The walls of this sac are thin and translucent, and are thickened by a number of longitudinal white strands, which are due to the internal wall of the sac being folded into complex longitudinal ridges (fig. 6 *a*). These ridges suggest that the walls of the sac secrete the odorous fluid; but the free surface is covered by a well-marked cuticle which is very impervious to staining fluids, and one would suppose equally so to secretions. The left sac of the stink-gland lies outside the left dorso-ventral muscles, and the narrow posterior end passes to the left of the rectum to open close to the aperture of the right one. It does not reach so far forward as the right one, but ends in the middle of the fifth segment. The

structure and appearance are precisely similar to what has already been described. This asymmetrical arrangement of what one must regard as a morphologically symmetrical structure is interesting on account of its rarity. The Arthropoda are essentially bilaterally symmetrical animals, and yet here we have a bulky organ disposed in a completely unsymmetrical way, and that without appreciably affecting any of the other organs in the same region of the body. The extreme ventral position of these sacs is also worth noticing, as it is but seldom that any structure of importance comes to lie between the nerve-cord and the ventral surface.

Twisting about on both sides of the central or right stink-sac, but more especially on the right side, where there is more room, is a convoluted mass of fine tubules. The convolutions are so complicated and the tubules so fragile, that I have not been able to ascertain how many tubules are present or whether they branch or anastomose. This last is probably not the case, as I could scarcely have failed to get some trace of branching if it were present. I have traced two of these tubules apparently opening into the distal, *i.e.* anterior, end of the left stink-sac, and have little doubt that others open similarly into the right one. I take these tubules to be the purely secretive part of the stink-gland, and imagine that they discharge their secretion into the sacs, from which it is ejected in considerable quantities when necessary.

The *coxal gland* (Pl. III. figs. 2 and 4, *cox.*) lies in the thorax on either side of the entosternite, the processes of which pass dorsal to it. It is an elongated body with a wavy outline, and the convolutions of the tube of which it is composed may be seen on the surface. At the front end it gives off a duct which runs alongside the foremost process of the entosternite, and then curving outwards passes into the base of the third appendage. I have been quite unable to find any aperture on the external surface in this region, but there is a considerable membranous area in which such an aperture might easily be overlooked. At the same time it is quite possible that the duct may be closed in the adult, or only open at special seasons as in *Mygale*.

The *lung-books* are situated, as has been already stated, towards the sides, beneath the first and second abdominal sclerites. The lamellæ lie for the most part horizontally, though curving up a little towards the outside. Each lamella has a comparatively short posterior edge where it abuts on the air-space (fig. 8).

The two sides run forward, diverging from each other, the outer side being the longer, and the anterior edge runs obliquely forward and outward. A thin chitinous cuticle covers both sides of each lamella, between the two layers of which is the blood-space. Occasional cellular columns pass across the blood-space from one cuticle to the other. The cuticle on the dorsal side of each lamella is covered towards the free margin (Pl. IV. fig. 9) by a number of vertical chitinous rods, the summits of which are united to form an arcade structure. Further away from the free margin these rods become smaller (fig. 10), and seem to be firmly attached to the ventral surface of the overlying lamella. Whether the ordinary small rods are actually continuous with the chitin of the overlying lamella, I cannot be sure, but certain thicker rods which occur here and there certainly are continuous. There is in this region no appearance of an arcade structure. The free edge of each lamella is enormously thickened (fig. 9), the thickened rim tending to run into sharp points on the dorsal surface and along the edge, while it is smoother and more solid on the ventral surface. The arcade structure gradually dies out towards the edge, though it persists for some distance along the thickened portion.

The posterior side of the air-chamber is bounded by a membranous wall, which is strengthened by a network of curved chitinous bars (Pl. IV. fig. 11). These bars are every here and there drawn up into blunt processes, and small knobs of chitin make their appearance on the membrane within the meshes. At the sides of the air-chamber where the ends of the free edges of the lamellæ are attached to it, the wall is enormously thickened (fig. 12) and drawn out into irregular conical processes. The surface of this part of the wall is further closely covered with stiff hairs.

The structure of these lamellæ differs from that described by Berteaux * for Spiders chiefly in the greatly thickened free margin. In other respects the similarity is very close.

Caudal Organ.—On the dorsal surface of the last segment lies a pair of oval white spots, which have been called the apertures of the stink-glands (fig. 1, *c.o.*). Sections through this portion of the integument, however, show that there is no aperture at this point. The chitinous cuticle is much thinner than elsewhere (Pl. III. fig. 7), and the underlying layer of cells shows an entirely

* La Cellule, vol. v.

different form. Over the rest of the body the hypodermis consists of somewhat flattened cells with circular nuclei, but in the region of this caudal organ the cells are columnar with large oval nuclei. In one dissection I thought I could trace a nerve to these cells, but I could not be certain. The appearance of these columnar cells suggests a sense-organ rather than a gland, and indeed we have found the stink-gland to be an entirely different structure. What sense this organ serves is, however, not so clear. It is almost certainly not an organ of sight, as there is no pigment in or around the cells and the overlying cuticle shows no modification for any optical purpose. It is probably then either auditory, olfactory, or for the sense of temperature, as are the lyriform organs of Spiders according to Gaubert *, but which must be left undecided until the minute structure can be investigated on properly preserved material and experiments made on the live animal.

II. Some Embryos of *Phrynus*.

While examining the Pedipalpi in the British Museum collection, Mr. Pocock directed my attention to a few specimens of *Phrynus* which had embryos attached to them. Inasmuch as practically nothing is known of the development of these forms †, it seemed well worth while to examine what embryos there were, though the number of specimens and state of preservation were evidently not such as to make anything approaching a satisfactory account possible. Through the kindness of Dr. Günther I have been able to cut sections through four stages, and have made out a few points which are, I think, not devoid of interest. Unfortunately, two of the four stages were too badly preserved to show anything, so my results are based on two somewhat late stages.

The development of *Phrynus* takes place, not, as usually stated, within the mother, but the embryos are carried in a sac formed of dark brown transparent gelatinous-looking material attached to the ventral surface of the mother (Pl. V. fig. 18). The abdomen is concave on the ventral surface where this sac is present, and the dorso-ventral measurement is so much reduced that it seems a question how the organs necessary for existence can be contained

* Ann. Sci. Nat. sér. 7, vol. xiii.

† Bruce, Johns Hopkins University Circulars, vol. vi. 1886, describes only a few points, and that without figures.

in it. By what means the sac is formed and attached, I have not been able to find out. It coincides in shape with the abdomen, of which it covers all except the first two segments. The anterior part of it and the sides are thin, but the greater part of the ventral surface is covered by a roughly quadrilateral thicker portion, the margin of which is thicker than the rest. At the posterior end—at least in *Phrynus reniformis*, in a specimen of which the sac was best preserved—this thickened portion runs out into two short acute triangular processes. This method of carrying the young agrees with what is known of the habits of *Thelyphonus*.

As mentioned above, the only embryos of which I have been able to cut sections are in a comparatively advanced stage of development. One specimen of *Phrynus reniformis*, however, in the British Museum was apparently at an early stage (Pl. V. fig. 19). In surface view it consisted, as nearly as one could ascertain, of a large cephalic lobe followed by seven or more paired white blocks, extending round about half of the spherical egg. It was evident that only the thicker parts of the embryo were visible, and I take it that the paired blocks are the mesoblastic somites of the embryo, while the cephalic lobe is due to the thickening to form the brain. In the absence of sections, however, any attempt to determine these characters can scarcely be trustworthy.

The older embryos have already the limbs well developed, and the body has undergone reversion similar to what occurs in Spiders (Pl. V. figs. 20 and 21). Just above and a little in front of the base of the fourth pair of limbs is seen a sac-like expansion, the surface of which, as also that of the body and legs in the immediate neighbourhood, is covered with a dark layer, apparently formed by the coagulation of some liquid excretion. In section the sac is seen to be hollow, but it was not possible to trace the cavity into connection with that of any other organ. The cuticle covering the sac is peculiar in that it is covered with blunt, conical, hollow processes which I believe are perforated. The cells forming the wall of the sac having drawn away from it owing to preservation, it was impossible to say whether processes from them extend into the cuticular processes or not, but I am inclined to think that such processes existed.

The presence of this sac was noticed by Bruce*, and a similar

* Bruce, A. J., "Observations on the Nervous System of Insects," &c. Johns Hopkins University Circulars, vol. vi.

organ has been described in *Galeodes* by Croneberg *. Bruce considers it to be a sense-organ, while Croneberg compares it with the paired processes in *Asellus*, which probably represent the remains of the shell.

Bruce has described a cellular amnion round his embryos. Of this I can find no distinct trace, but it may have atrophied at an earlier stage.

The embryo appears, however, to cast off at least one cuticle in the course of development. This cuticle follows roughly the outlines of the body, and seems to be cast off during the later stages of the process of reversion, as there are cross partitions between the layer covering the cephalothorax and that over the abdomen. Between these two layers, and therefore outside this cuticle, there are traces in one of my embryos of a thin-walled sac with granular contents, but whether this is the remains of a still earlier cuticle or not I am unable to say.

The Gut (Pl. V. fig. 21).

The gut is composed, as usual, of three well-marked divisions—Stomodæum, Mesenteron, and Proctodæum. The stomodæum is a narrow tube extending from the mouth to a little behind the brain. In front of the brain there are attached to it powerful muscles running dorsally to be inserted in the carapace behind the median eyes. Lateral muscles are also present in this region, which no doubt has a suctorial function, though there is no sign of any dilatation to form a sucking stomach. Close behind the brain and just in front of the junction between the stomodæum and the mesenteron are inserted some more muscles which also pass dorsally to the carapace.

The anterior part of the mesenteron—*i. e.* the part lying in the cephalothorax—is dilated to form a sort of stomach as in *Thelyphonus*. The dilatation seems to take the form of a single pair of lateral outgrowths, very similar at this stage to the lobes of the "liver." A small median ventral outgrowth is also present, and reminds one of the median processes in *Thelyphonus*. The middle part of the mesenteron is very short, only extending as far back as the fourth free segment. There are four pairs of diverticula forming the so-called liver, of which the first three divide almost immediately into a dorsal and ventral portion. The "liver" lobes of these three are small and well defined, the

* Croneberg, Zool. Anz. 10 Jahrg. 1887.

ventral part of the first two being much smaller than the dorsal. They are placed in front of the first dorso-ventral muscle (*i. e.* the muscle of the second segment), and between the first and second, and the second and third dorso-ventral muscles respectively. The fourth diverticulum is very much larger than the others, and runs back along each side of the gut, somewhat dorsal to it. It opens into four secondary lobes on the ventral side, lying in the 4th, 5th, 6th, and 7th segments respectively, and is continued, though much reduced in size, as far as the posterior end of the body.

Behind this middle section of the mesenteron comes a considerable length of narrow intestine, which expands about the seventh segment into a great oval stercoral pocket which reaches to the posterior end of the body. This stercoral pouch is in absolute continuity with the rest of the gut, and is, I have no doubt, derived from the hypoblast.

The proctodæum consists of a solid mass of cells, which comes into contact with the closed posterior end of the stercoral pocket. The cells are, however, quite different in appearance from those lining the stercoral pocket, and though in contact, the line of demarcation is perfectly distinct.

The Nervous System.

I have been able to make out but little as regards the development of the nervous system, as in my younger stage it is practically fully formed, though, as is usually the case with embryos, far larger in proportion than in the adult. The ganglion for the cheliceræ is quite distinct from the brain in my embryos. Ganglion, by the way, used in this sense has exactly the opposite meaning to that in Vertebrata. In the latter it means a collection of nerve-cells, while in the Arthropod cephalothoracic nervous system it means a mass of white substance among the nerve-cells. Behind the ganglion for the cheliceræ are five, somewhat larger similar ganglia appertaining to the five other appendages. Then come six very small separate masses of white substance, and finally a single elongated mass from which the nerve-cord runs out. I have not found in these stages any distinct division of the cerebral ganglion into three, such as has been described for *Limulus* * and Spiders. The distinction between the cells forming the dorsal mass of the cerebral ganglion and those lying

* Patten, Q. J. M. S. vol. xxxv.

on its sides is well marked here, as in Scorpions, the former being smaller and more closely packed.

The central eyes are formed, as in Scorpions * and Spiders †, by an in-pushing from in front of where the eye is about to be formed, the dorsal wall of which in-pushing forms the retinal cells, while the ventral wall forms a layer of flattened cells bounding the retina on its ventral side. The nervous system being already separated from the skin in my younger embryo, I cannot say whether or not part of the cerebral ganglion is formed from the optic in-pushing as in Scorpions. As in other Arachnids, the central eyes are diplostichous and the lateral eyes monostichous, the latter being formed by a modification of the hypodermis-cells *in situ*.

Coxal Gland.

The earlier stages of this structure are not represented in my specimens. In the younger it is already a considerably coiled tube. The tube is lined by cubical epithelium, the cells of which have round lightly-granular nuclei. Towards the front end a duct passes from the coiled tube and opens to the exterior on the posterior face of the basal joint of the third appendage (Pl. V. fig. 23). The epithelium lining the duct differs from that of the coiled tube, the nuclei being more closely packed, somewhat larger, oval, and more darkly staining. They resemble pretty closely the nuclei of the hypodermis, and as the duct has a thin cuticular lining, it probably represents the ectodermal part of the coxal gland. No trace of an enlarged terminal sac, such as that described by Faussek ‡ in *Phalangium*, could be found, but it may be present in younger stages.

The Respiratory Organs.

The lung-books in the Pedipalpi are two in number, the first lying under the large genital plate, and the second under the next sclerite, which corresponds to the third free segment. An early stage of development is shown in Pl. V. fig. 22, which is a longitudinal section to one side of the middle line. i. is the genital plate, and iii. the sclerite immediately behind it. The two resemble one another so closely that a description of one of them will serve for both. iii., then, consists of a distinct outgrowth

* Laurie, Q. J. M. S. vol. xxxi., and Parker, Bull. Mus. Comp. Zool. Harvard, vol. xiii.

† Locy, Bull. Mus. Comp. Zool. Harvard, vol. xii.

‡ Faussek, Travaux de la Soc. d. Nat. St. Pétersb. vol. xxii. (Russian); Abstract in Biol. Centralbl. 1892.

from the body-wall, the cavity of which contains at this stage a certain number of mesoderm-cells. The hypodermis over the greater part of it is very much like that of the rest of the body. On the posterior surface, *i.e.* the surface next to the body-wall, however, the inner two-thirds is thickened, and the cells of the thickened portion are beginning to arrange themselves in rows more or less at right angles to the surface of the outgrowth. This is the beginning of the lung-book. That this lung-book belongs to the segment to which it is at this stage attached and not to the one behind it is, I think, fairly certain. With regard to the first lung-book, which appears to be attached to the posterior surface of the genital plate, it is not so evident to which segment it belongs. The genital plate covers the ventral surface of the first two segments, and the lung-book may either be attached to the genital plate, and therefore belong morphologically to the first segment, of which the genital plate is the appendage, or it may be the sole survival of the appendage of the second segment, which has otherwise entirely disappeared. This last I have suggested as being the case in the Eurypteridæ *; and I believe it to be the correct explanation in these forms also, but only an examination of earlier stages can prove it. At all events, it is pretty certain that the first lung-book belongs to segments i. or ii., and not to segment iii. It is therefore not homologous with the first lung-book of the Scorpion, which does belong to segment iii., but is either the homologue of the pectines of the Scorpion, *i.e.* appendage ii., or is a special structure, the appendage of segment ii. having entirely vanished. The former is evidently more probable *a priori* †.

Of the development of the other organs I have not been able to make out anything of importance. The whole of this paper is, I feel, calculated rather to show what we may expect when the embryology of this group is properly worked out than to say what actually happens. If I have shown what important results a study of these forms will almost certainly give us, and how heavily handicapped any attempt to deal with the morphology of the Arachnida must be until such a study has been made, I have done all that I expected with the material at my disposal.

* Trans. R. S. Edinb. vol. xxxvii.

† A paper on the "Development of the Lungs in Spiders," by O. L. Simmons in the Am. Journ. Sci. Nat. for August 1894, shows very similar structures, and the author's conclusions agree for the most part with mine.

General Considerations.

In the following pages I only propose to consider a few points in Arachnid morphology on which it seems to me that my observations have thrown some light. Many points—such as the existence of a number of pre-oral segments in the embryo—I have not dealt with, because it seems better to wait for further observations rather than to try and generalize on a manifestly insufficient basis.

Post-oral Thoracic Appendages.

Gaubert *, in his recent paper on the Arachnids, treats of the limbs of the terrestrial forms at some length, but his conclusions do not appear satisfactory to me. He considers the typical walking-leg of the Arachnids to consist of six segments, the articulations between which are capable of dorso-ventral motion. Antero-posterior motion has been acquired in most forms, but always by the formation of a secondary joint, which has arisen in various parts of the leg in different forms. Thus, in Pedipalpi, Phalangidæ, and Spiders the fourth segment has been divided; in Scorpions the fifth, and in *Galeodes* the third. That secondary jointing does take place in some forms is certain, but that all the articulations capable of antero-posterior motion are due to it I doubt. In the figure on p. 37 I have drawn a number of legs of different forms, a glance at which will make my views clearer than pages of description. The numbers *above* each figure are those of the segments of the limb as I interpret them, those in brackets below are according to Gaubert. The articulation capable of antero-posterior movement is marked with an asterisk. In a primitive limb, then, for a type of which I will take that of one of the Eurypterids, we have seven segments, of which the first is modified for mastication, and the articulations of which are capable of movement in any direction. Appendage ii. seems, in contradistinction to the rest, to have only six segments in all forms. The following are the chief modifications which have taken place in the various orders :—

(a) *Eurypterids*.—Appendage ii. may have a tactile function, as in *Slimonia*. Appendage vi. is always larger than the rest and usually flattened to form the swimming-foot. In *Stylomerus*, v. and vi. are enormously elongated. An epicoxite is present in some of the limbs.

* Ann. Sci. Nat. sér. 7, vol. xiii.

(b) *Limulus.*—The masticatory function is retained throughout. Appendage ii. has six segments and is chelate. Appendages iii.–vi. are always described as having six segments, but there is distinct evidence of a fusion of segments 4 and 5. Appendages iii.–v. are chelate, while vi. bears a number of spines at the articulation between 6 and 7, and also at the end of 7. There is,

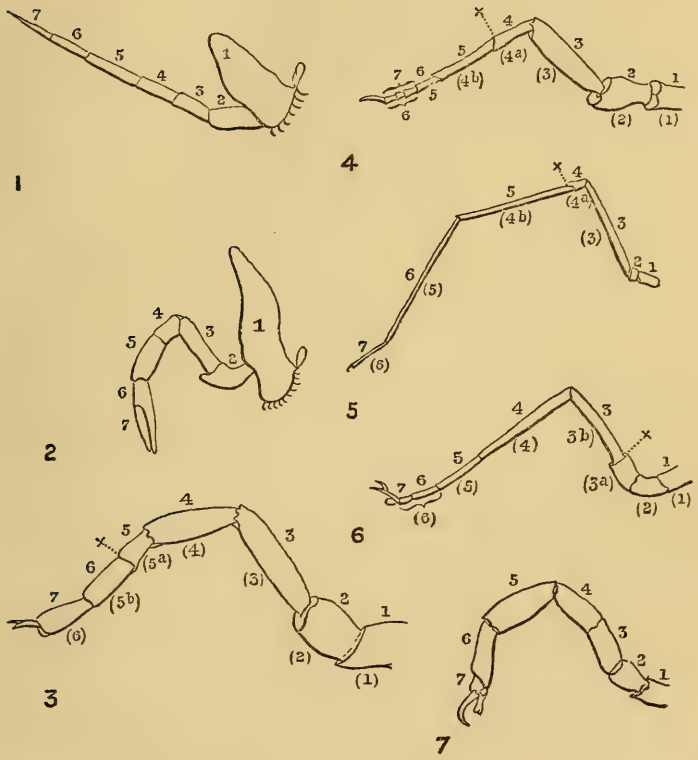


Fig. 1. *Pterygotus.* Fig. 2. *Limulus.* Fig. 3. Scorpion. Fig. 4. *Thelyphonus.* Fig. 5. Spider. Fig. 6. *Galeodes.* Fig. 7. *Pseudoscorpion.*

further, a curious outgrowth from the external side of segment i., which seems to be of importance, as it is well developed at a comparatively early stage*, but the morphological significance

* Kingsley, Journ. Morph. vii.

of which is unknown. An epicoxite is present in appendages iii.–v.

(c) *Scorpions.*—The masticatory function has been lost, except in appendage ii., though the expanded first joint persists in iii. and iv., and serves to shut in the mouth behind. An epicoxite is present in iii. * The third segment has an ascending position, the fourth is almost horizontal. The articulation between 5 and 6 is modified for antero-posterior motion.

Pedipalpi.—The masticatory function is retained in appendage ii. in *Phrynus*, but not in *Thelyphonus*, in which the first joints of this limb are fused and perform the function of appendages iii. and iv. of the Scorpion. Appendage iii. is modified as a tactile organ, the last four joints in *Phrynus* and the last three in *Thelyphonus* being secondarily segmented. The first segment of appendages iv.–vi. is fused to the body—more completely in *Thelyphonus* than in *Phrynus*. Segment 3 is ascending in direction in these limbs, and the rest descending. Articulation 4–5 is modified for antero-posterior motion, and segment 7 forms a three-jointed tarsus. Appendage vi. in the Phrynidæ undergoes secondary segmentation of segment 5 in many forms. *Phrynichus* (*ceylonicus*) has the segment normal; *Damon* (*medius*) has it divided into two; *Tarantula pumilis* (C. L. Koch) has three segments in this region, and *Phrynus Grayi* (?) four †.

Araneidæ.—These are similar in arrangement to the Pedipalpi, except that segment 7 is not divided up into a tarsus. Appendage ii. is tactile, not prehensile, and undergoes curious modifications in the male.

Phalangidæ.—The masticatory function is retained by appendages ii. and iii., while appendage iv. has still a process projecting towards the middle line. The rest of the limbs are similar to those of Spiders, except that segment 7 is divided into a many-jointed tarsus.

Galeodes.—The masticatory function is entirely lost. Appendage iii. is slightly modified for tactile purposes, having practically lost the claw and apparently segment 7. This loss of a segment is curiously in contrast with the multiplication of segments in the corresponding limb of the Pedipalpi. In appendages iii. and iv. an additional joint is intercalated between segments 2 and 3. This may be due to division of segment 2,

* Lankester, Q. J. M. S. xxi.

† Karsch, "Zur Kenntniss der Tarantuliden," Arch. f. Naturg. vol. i.

but more likely, as Gaubert suggests, to division of segment 3. Antero-posterior motion takes place between this additional segment and 3. In appendages v. and vi. a second segment is intercalated in this region. Whether the intercalated segment is connected with a horseshoe-shaped strip of chitin which strengthens articulation 2–3 in the Pedipalpi or not, is an interesting point which must remain for the present unsolved.

Pseudoscorpions.—In these minute forms the masticatory function has been lost, except in appendage ii. In the other limbs segments 3 and 4 are fused together, their line of junction being marked by a groove, while segment 7 is so reduced as to have been overlooked by everyone except Croneberg. The limbs are exceptional in that the division between the ascending and descending portions of the limb occurs at articulation 4–5 instead of articulation 3–4.

Acarina.—The limbs here seem to have only six segments, but my researches have not led me to any conclusion as to which segment is lost. Appendages i. and ii. are variously modified in connection with the modes of life of the different forms. As being a degenerate group derived probably from the neighbourhood of the Phalangidæ (Bernard says from the Araneidæ) they need not detain us here.

To summarize the results obtained from the above brief account of the appendages, the terrestrial forms seem to differ from the aquatic ones (*Limulus* and *Eurypteridæ*) in that the majority of the appendages have lost their masticatory function. This confinement of mastication to a smaller area seems to me a natural result of terrestrial life in such forms as these, which suck in their food in a liquid form, since a contingency to be by all means avoided is evidently that the juices on which they subsist should dry up. Beyond this the modifications of the appendages would seem to unite the Pedipalpi, Phalangidæ, and Araneidæ together as a natural group. The Scorpions differ from them on one side, and *Galeodes*, as usual, stands alone on the other, though apparently showing affinities to the Pedipalpi. The condition of things in the Pseudoscorpions points either to their type of limb being independently derived from a comparatively primitive form, or to their having passed through a much simplified stage, like the Acarina. I think the latter more probable, though I wish it to be distinctly understood that I do not propose to derive the Pseudoscorpions from the Acarina.

Abdominal Appendages and Respiratory Organs.

The full number of abdominal appendages (six) only persist as such in *Limulus*. In this form they are somewhat modified, the plates of each pair being connected in the middle line. That this connection is secondary is evident from Kingsley's * figures, which show the abdominal appendages quite distinct from each other in early stages. The other aquatic forms, the Eurypterids, differ from *Limulus* in the segmentation of the abdomen. The first appendage is fused in the middle, and bears a well-developed median lobe, which probably has some function in connection with reproduction, and is in some forms at any rate capable of partial invagination. The second abdominal segment is covered by this genital operculum and has no plate-like appendage, though it bears a number of branchial lamellæ. The third to sixth segments bear paired plates with branchial lamellæ on their posterior surfaces. The sternites persist in these segments; at all events in *Slimonia*—and this, one would expect, as a segmented abdomen demands greater strength than one in which the segments are fused together as they are in *Limulus*.

I have stated elsewhere† what I believe to be the case as regards the morphology of the anterior abdominal segments in *Scorpio* and the Pedipalpi. To recapitulate briefly, the Scorpions have all the segments well-developed, the second segment bearing the pectines, and the third to sixth having lung-books. The genital plate is small and does not overlap the second segment. In the Pedipalpi the genital plate covers two segments as in Eurypterids, the second of which bears the first pair of lung-books, which consequently lie under the genital plate. The third segment is also covered by an appendage under which lie the second pair of lung-books. I think the anatomy and still more the development, as described above, fully bear out this view. There can be no doubt that the first pair of lung-books in the embryo *Phrynus* belong to the region covered by the genital plate and not to the third segment. The first pair of lung-books in the Pedipalpi thus correspond to the pectines of Scorpions. Another difference between the lung-books of these forms seems to be that in *Scorpio* they are formed, as I have elsewhere maintained‡, from paired appendages not united in

* Journ. Morph. vii.

† Trans. R. S. Edinb. vol. xxxvii.

‡ Zool. Anz. 1892, no. 386.

the middle line, but in the Pedipalpi the appendages stretch right across, as Macleod * suggested for spiders.

This view differs from that which has recently been set forth by Pocock †, who regards all the sclerites as sternites, and considers that the ventral side of the second abdominal segment has been crushed out by the great development of the first, which extends so far back as to cover part of the third segment, including the first pair of lung-books. The second sternite, that of the third segment, has, according to him, been pushed back by the same growth so as to cover the second pair of lung-books, which belong to the fourth segment.

Schizonotus, which I have unfortunately not had an opportunity of studying, is thus described by Pocock :—" There appears usually to be a single pair of respiratory stigmata situated behind the first sternite, as in *Thelyphonus*. The posterior pair that are developed in *Thelyphonus* appear to be functionless, but upon the third, fourth, and fifth sterna (morphologically the fourth, fifth, and sixth), close to the posterior margin and behind the muscular impressions, a pair of dusky patches are visible. These appear to be some internal organs seen through the semi-transparent cuticle, and I believe they are the homologues of the three posterior pairs of lung-sacs of the Scorpion"‡. If this interpretation of these structures be correct, we have here traces of the posterior abdominal appendages which have entirely disappeared in *Thelyphonus* and *Phrynus*.

In *Spiders* the same arrangement is found as in the Pedipalpi. This is particularly clear in that curiously primitive form *Liphistius*, which has been recently described by Pocock §. In this form the segmentation of the abdomen is marked on the dorsal side by nine (Schiödte) chitinous tergites. On the ventral side there are two large chitinous plates, the anterior of which covers the genital aperture and the first pair of lung-books, while the posterior covers the second pair of lung-books. These two chitinous plates I would regard as the two appendages which are found in the Pedipalpi. A further argument in favour of my view is that the lung-books have been described as developing in connection with the appendages of the second abdominal segment.

* Arch. de Biol. vol. v.
† Ann. & Mag. Nat. Hist. vol. xi. 1893.
‡ *Tom. cit.* p. 4.
§ *Op. cit.* vol. x. 1892.

In the Dipneumones the posterior pair of lung-books are replaced by tracheæ which, according to this view, have developed by an extension of the air-chamber of the lung-sac, as has been suggested by Macleod*.

Two pairs of abdominal appendages seem to be converted into spinning mammillæ in the Araneina. In *Liphistius* they occupy a normal position on the ventral surface of the abdomen, but in the higher forms, in which the segmentation of the abdomen has been entirely lost, they are shifted to a posterior position. This accounts for five appendages of the abdomen, which is all that seem to appear in the embryo. It may be advanced as an argument against my view, that if we consider the second lung-book as belonging to the fourth abdominal segment instead of the third, then we have, with the spinning mammillæ, all six abdominal appendages accounted for; but it seems to me more likely, without considering other reasons, that the sixth appendage has vanished than that the second has disappeared without leaving any trace.

In the other Arachnids the lung-books are replaced by tracheæ. Of *Galeodes*, the *pons asinorum* of all who have tried to deal with Arachnid morphology, I do not intend to speak here. The presence of stigmata leading into tracheæ between the fourth and fifth thoracic appendages is perplexing, not to say bewildering. I fully agree with Bernard in considering this form of great importance, though I do not feel convinced of its being primitive in most respects. We must wait, however, till we have a more careful and detailed account of its anatomy than has yet been published before we can speculate as to its morphology with any hope of success.

It has often been maintained that the lung-books of Arachnida are derived from tracheæ and not from branchiæ; but this view cannot, I think, be accepted. The fact that lung-books are characteristic of the two most primitive orders—the Scorpions and the Pedipalpi—while in the Spiders, in which both are present, it is the higher forms—the Dipneumones—which have tracheæ, affords a strong argument against it. It is said that the independent development of tracheæ so closely resembling each other in the Insects and Arachnids cannot be thought of as possible; but

* Arch. de Biol. vol. v.

if we attempt to begin from tracheæ we find that lung-books, more closely resembling each other, have to be independently developed twice, or more probably three times, so we are not much advanced. Further, the similarity between the tracheæ of Arachnids and Insects has been much overrated. It seems to depend mostly on the spiral thickening, which is present in both cases; but a thickening of some sort is evidently a mechanical necessity in these structures, and also the "spiral" is very poorly developed in many Arachnids. The difference of position, too, must have some morphological significance,—the tracheæ of Insects &c. arising outside the attachment of the appendages, while those of Arachnids are inside. Bernard * would derive the tracheæ of both forms from setiparous sacs, and makes a great point of the thoracic stigmata of *Galeodes*. *Galeodes* is a difficult problem, whichever view we take, but far too little is known of its anatomy (and still less of its development) to make it a safe basis for generalizing from. It is to be hoped that Dr. Bernard's forthcoming paper on this form will give us some surer ground on which to base our speculations. He talks of the "fascinating but seductive" hypothesis that the lung-books are derived from branchiæ; but it seems to me that a plentiful supply of setiparous sacs, capable of developing at will into lung-books, tracheæ, or coxal glands, affords a still more "fascinating" hypothesis, and is, I am afraid, equally seductive. I do not think that, in face of the development of the lung-books in *Phrynus*, where they evidently arise as foldings of the posterior wall of an appendage, it is possible to entertain the idea that they are derived from setiparous sacs, and they do not seem to give much indication of being derived from tracheæ. It is unfortunate that the development of the tracheæ in Arachnids has never been fully described, for I cannot but think that it would give some indication as to whether they are primitive or derived from lung-books †.

The Coxal Gland.

There can be little doubt now but that this structure is morphologically a nephridium. It has been shown to develop in part from the mesoderm, and in the earlier stages to open into

* Zool. Jahrb. vol. v., and Ann. & Mag. N. H. vol. xi. 1893.

† *Vide* Simmons, Am. J. Sci. Nat., Aug. 1894, and Ann. & Mag. N. H., Sept. 1894.

the cœlomic cavity in *Limulus*, *Scorpio*, *Phalangium*, and Spiders, and the structure in the adults is much the same in all these forms. Bernard * again suggests setiparous sacs as the origin of the coxal glands, but I do not think he can have understood the significance of what has been described in their development. Setiparous sacs, partly developed from the mesoderm and opening freely into the cœlom, do not commend themselves to one as morphological probabilities. The differences in the various forms have been so fully treated of by Sturany † that it seems unnecessary to recapitulate the details here. The one point on which I wish to lay some stress is the difference which exists as to the segment to which the coxal gland belongs. In the Scorpion and *Limulus* it opens at the base of the fifth pair of appendages. Kowalevsky and Schulgin ‡ describe it as belonging to the third in *Androctonus ornatus*; but my sections of *Euscorpius italicus* and *Centrurus* leave no possibility of doubt that in these forms it is the fifth, and as they themselves seem not very certain, I think it probable that they were mistaken. In *Phalangium*, *Phrynus* (*supra*), and Spiders this organ opens at the base of the third pair of appendages. Bertkau § says he has seen ducts to the fifth pair of appendages in *Atypus*, and Sturany says also that the gland opens on the fifth in the Tetrapneumones. In Pseudoscorpions it opens on the "third leg"—which, I presume, means the fifth pair of appendages—according to Bernard.

It seems, then, that while the coxal glands are serially homologous in different forms, they belong to different segments, and by this character alone the Arachnida would be divided into two sections—one containing the Scorpions and *Limulus*, in which the gland opens on the fifth appendages, and the other the rest of the group, in which there is a gland in the third segment, with the possible exception of some Spiders and Pseudoscorpions. A gland may also be present in the fifth segment in these forms. The antennary and shell-glands of Crustacea are no doubt structures of the same kind but belonging to different segments, *i. e.* either the second and fifth or first and fourth, according as one does or does not count the first antennæ as somatic appendages. Consequently,

* Ann. & Mag. vol. xii. 1893.
† Arb. Zool. Inst. Wien, vol. ix.
‡ Biol. Centralbl. vi.
§ Arch. mikr. Anat. vol. xxiv., and Zool. Anz. xcii.

we must regard both the Crustacea and the two sections of Arachnida as having for their common ancestor a form with nephridia in each segment.

The Gut.

The only point on which I wish to make a few remarks in this connection is the origin of the stercoral pocket as I have described it above. There is no doubt in my mind that in *Phrynus* it is formed from the mesenteron. The position of the Malpighian tubes, which I discovered after I had completed the section dealing with *Phrynus*, as running in close contact with the wall of the stercoral pocket, to open into it at its posterior end, is absolutely conclusive, though the evidence from histological structure and anatomical relations in *Phrynus* and *Thelyphonus* was pretty strong already. In Spiders, however, it is always described as being formed from the proctodæum; and the question arises whether the stercoral pocket in Spiders is not analogous with that of Pedipalpi, or whether the development has not been properly described. I incline to the latter view. That the development of this part of the gut is not quite straightforward is, I think, evident from the fact that Kishinouye *, in his elaborate paper on the development of Araneina, describes it as formed from the unpaired caudal cœlom. Such a startling suggestion as this certainly requires independent confirmation, and I think that possibly Kishinouye has mistaken the early formed posterior part of the gut for cœlom. However this may be, Kishinouye's figures seem to make it pretty clear that the stercoral pocket has no connection with the proctodæum, which at this stage is represented by a solid plug of cells, just as it is in *Phrynus*. The formation of the Malpighian tubes in the Spider has also never been quite satisfactorily described, and if they run in close contact with the stercoral pocket, as they do in *Phrynus*, they might easily be mistaken as opening into the anterior end of the pocket. Kishinouye admits that he is not satisfied with his observations on the origin of these structures, and the description by other observers is hardly more satisfactory than his. Locy's description † is brief, and his figures are capable of a different interpretation to that which he gives them: fig. 57, in particular, seems rather in favour

* Journ. Coll. Sci. Jap.

† Bull. Mus. Comp. Zool. Harvard, xii.

of my view. Balfour* gives a very short account of this region, and does not say whether the stercoral pocket is formed from the proctodæum or not; and Morin gives no figures, and his account is brief and inconclusive. The point at all events will bear re-investigation.

Conclusion.

The ultimate summing-up of all morphological work is its embodiment in a classification which shall express the true relations of forms to each other. This I do not feel prepared to do as regards the Arachnids; but a few points may be touched upon. I have elsewhere † given some reasons for dividing the terrestrial forms into two subclasses similar to those suggested by Pocock ‡, and for considering the Scorpions as more nearly related to *Limulus*, and the rest of the Arachnids to the Eurypterids. A further argument may be found in the apparently invariable presence of a coxal gland on the third appendage in the latter section. The development of lung-books from branchiæ twice over would seem the chief difficulty in this view; but if, as I have tried to show, the first lung-books of Pedipalpi are equivalent to the pectines of Scorpions, the same difficulty faces us if we try the old hypothesis.

The mutual relations of the forms constituting the second subclass (termed by Pocock "Lipoctena") is not quite clear. That the Arachnids and Pedipalpi are closely related is evidenced by their possession of two pairs of respiratory organs, a stercoral pocket, similar cheliceræ, legs segmented in the same way, and a not very different disposition of the eyes. Beyond these two the different orders do not seem to show any very special relations to each other, and one is met at the outset by the difficulty concerning tracheæ. These are the common possession of the Phalangidæ, Spiders, Pseudoscorpions, and *Galeodes* That the tracheæ of Spiders have developed within the limits of that order is, I think, indisputable, as the Tetrapneumones, or at all events *Liphistius*, must be admitted as being the lower forms. But no possible arrangement enables one to derive the Phalangidæ, Pseudoscorpions, and *Galeodes* from the Dipneumones without violating every rule of morphological probability. It must be

* Q. J. M. S. xx.

† Trans. R. S. Edinb. vol. xxxvii.

‡ Ann. & Mag. Nat. Hist. vol. xi.

admitted that tracheæ have been formed from lung-books twice at least within the limits of the Arachnida. As I have already pointed out, any attempt to derive lung-books from tracheæ lands one in an equally awkward position. The three remaining orders—Phalangids, Pseudoscorpions, and Solifugæ—are unfortunately the three about whose morphology we know least. They seem absolutely marked off from each other—the Phalangidæ by their extraordinary reproductive apparatus; the Solifugæ by the segmentation of the carapace and the presence of thoracic stigmata; and the Pseudoscorpions by the absence of both of these sets. For these reasons I have refrained from attempting to construct a phylogenetic tree in this place, as it seems useless to try any arrangement of the Lipoctena (Pocock) until more is known both of their structure and development.

EXPLANATION OF THE PLATES.

Plate III.

Fig. 1. *Thelyphonus*, opened from the dorsal surface. The superficial muscles of the thorax have been removed. i.–vi., appendages; *c.o.*, caudal organ; *d.c.m.*, dorsal tail-muscle; *d.v.m.s.*, dorso-ventral muscle of eighth free segment; *g*, thoracic expansion of gut; *ht.*, heart; *o.c.*, central eyes.

1 *a*. Portion of trabecular tissue from anterior lobe of gut.

2. Transverse section of thorax of small *Thelyphonus*. *cox.*, coxal gland; *ent.*, entostermite; *g* and *g'*, diverticula of gut; *m.d.g.*, anterior median diverticulum of gut; *n.g.*, thoracic nerve-ganglion; *st.*, stomodæum.

2 *a*. Transverse section through stomodæum in front of fig. 2.

3. Stercoral pocket and proctodæum.

4. Thorax after removal of the gut. *c.e.*, cerebral ganglia; *cox.*, coxal gland; *cox.d.*, duct of coxal gland; *ent.*, entosternite.

5. Cerebral and thoracic ganglia. iii.–vi., nerves to appendages; *oc.*, optic nerves; *oes.*, œsophagus.

6. Posterior portion of abdomen after removal of gut and digestive gland. *n.g.*, nerve-ganglion; *r.*, rectum; *l.s.s.* and *r.s.s.*, left and right sacs of stink-gland; *s.g.*, coiled tubes of stink-gland.

6 *a*. Section through part of wall of stink-sac.

7. Section through caudal organ. *cu.*, cuticle; *hy.*, hypodermis; *s.c.*, sense-cells.

8. Anterior segments of abdomen. The anterior process of the second sclerite has been removed so as to open the genital vestibule. c^1 and c^2, chitinous supports of the genital vestibule; *ge.v.*, genital vestibule; *lb.*1 and *lb.*2, first and second lung-books; *se.v.*, dilatation of vas deferens; *x*, hard structure in *se.v.*

PLATE IV.

Fig. 9. Section of the free edges of two lamellæ of the lung-book.
10. Section through lamellæ of lung-book near their base.
11. Part of the wall of the air-space towards the centre.
12. Section of wall of air-space towards the side.
13. Side view of mouth and surrounding parts. The left first and second appendages have been removed and the thorax laid open. i. and ii., right first and second appendages; *car.*, carapace; *eps.*, epistome; *m.*, mouth; *p.s.t.*, sense-organ on base of appendage ii.
14. Ventral sclerites of second and third free segments, viewed from inside.
15. Section of wall of stercoral pocket.
16. Section of one of the Malpighian tubes.
17. Section of epithelium of proctodæum.

PLATE V.

Fig. 18. Ventral surface of abdomen of *Phrynus reniformis*, with egg-sac.
19. Young embryo of *Phrynus reniformis*: surface view.
20. Side view of embryo of *Phrynus annulatipes*, ×9. *l.o.*, lateral organ.
21. Schematic longitudinal vertical section of *Phrynus annulatipes*, ×. *o.e.*, median eye; *gen.a.*, genital aperture; *Sto.*, stercoral pocket; *Pr.*, proctodæum.
22. Longitudinal section of first four abdominal segments. ×.
23. Longitudinal section through front part of coxal gland and duct.

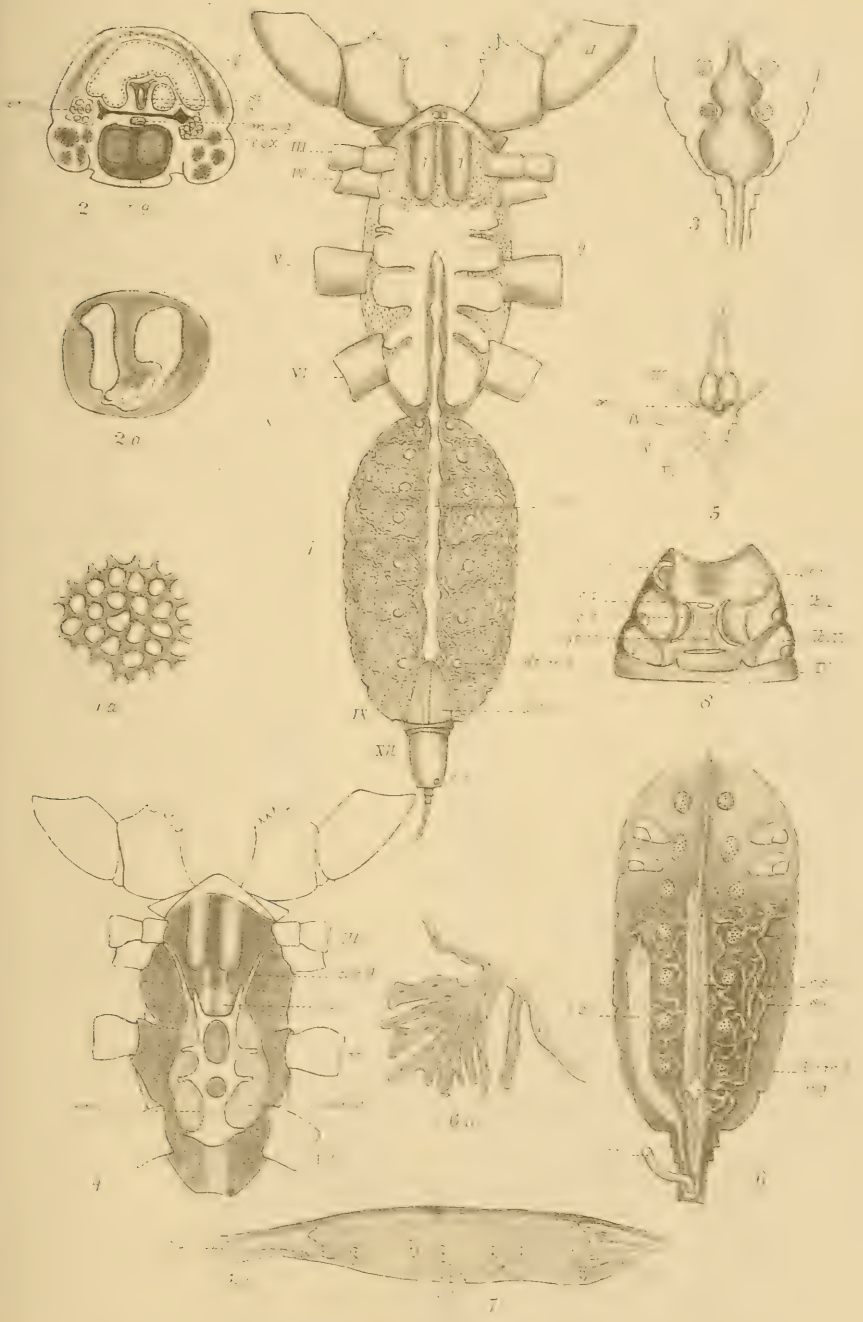
On the Aortic-Arch System of *Saccobranchus fossilis*.

By R. H. BURNE, B.A. Oxon., Assistant in Museum, Royal College of Surgeons, London. (Communicated by Prof. G. B. HOWES, F.L.S.)

[Read 5th April, 1894.]

IN tropical countries, but more especially in India, where the streams and tanks are liable to become dry in the hot season, a number of the freshwater fishes have acquired the power of living for a longer or shorter time out of water, and are thus enabled either to migrate to places where water is more abundant, or to bury themselves deep down in the mud to await the revivifying rains. Many years ago * reports that fish were often dug up in spots that had been dry for months, or were found

* For the early literature of this subject see Boake, Journ. Ceylon Branch Asiat. Soc. 1865, and Day, Proc. Zool. Soc. 1868, p. 274.



West, Newman lith. & imp.

MORPHOLOGY OF THE PEDIPALPI.

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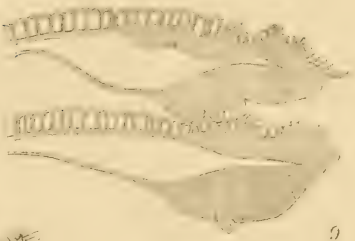

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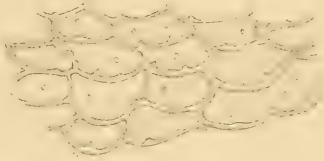

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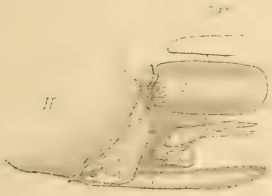

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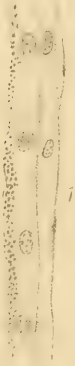

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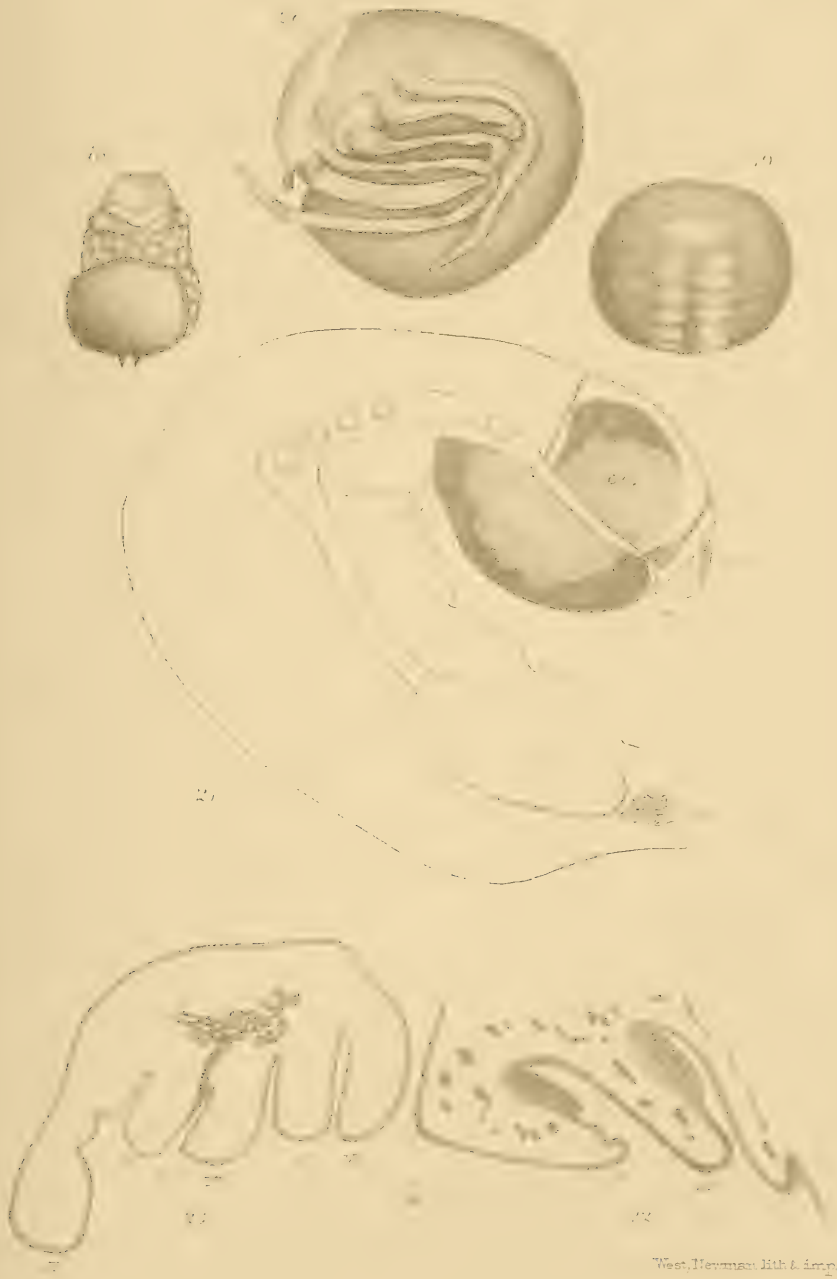

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